Bidirectional Reflectance Distribution Function of Rough Silicon Wafers

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The trend towards miniaturization of patterning features in integrated circuits (IC) has made traditional batch furnaces inadequate for many processes. Rapid thermal processing (RTP) for silicon wafers has become more popular in recent years for IC manufacturing. The major barrier for implementation of RTP in many industrial processes is accurate temperature measurement. Light pipe radiation thermometry is the method of choice for real-time temperature monitoring in RTP. However, the radiation environment can greatly affect the signal reaching the radiometer. In many process systems, the silicon wafers are polished only on the front side, while the preferable arrangement is for the radiometer to view the rough side of the wafer. The bidirectional reflectance distribution function (BRDF) of rough silicon wafers is needed for the prediction of the reflected radiation that reaches the radiometer and for reflective RTP furnace design.

The effect of surface roughness on the radiative properties is well known but difficult to model. Approximate and statistical theories have been developed for light scattering by nearly specular rough surfaces, where the rms roughness is much smaller than the wavelength. This theory has also been extended to scattering on very rough surfaces, under the assumption that the rms slope is small. Geometric optics has been applied to very rough surfaces with or without considering multiple scattering.

In this study, the BRDF of several processing wafers has been measured for wavelengths ranging from 0.4 μm to 1.1 μm by the NIST Spectral Tri-function Automated Reference Reflectometer. The rms roughness of these samples ranges from 1 nm to 4 μm, as measured with optical interferometric microscopes. Correlations between the BRDF and surface roughness data will be obtained using different models and the theoretical prediction will be compared with experiments.